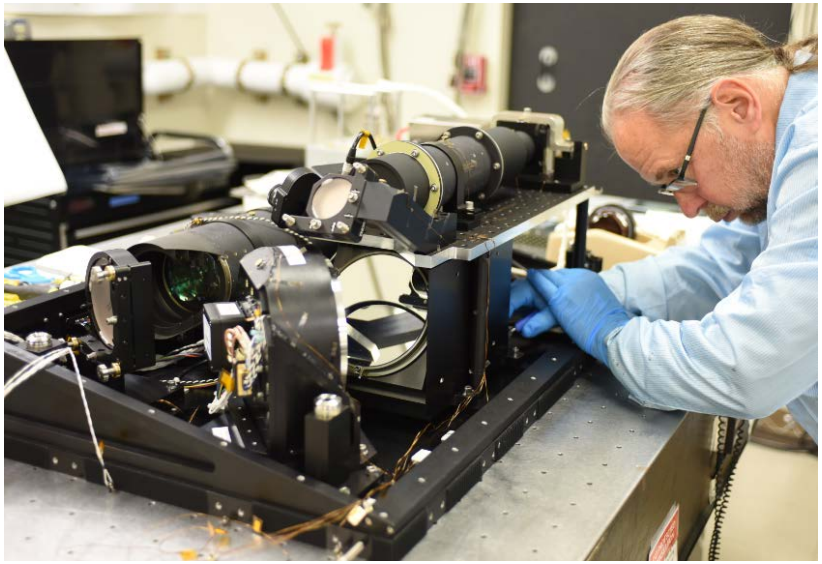


REMI - Reduced Envelope Multi-Spectral Imager for Sustained Land Imaging

Dennis Nicks, PI
Paul Kaptchen, PM

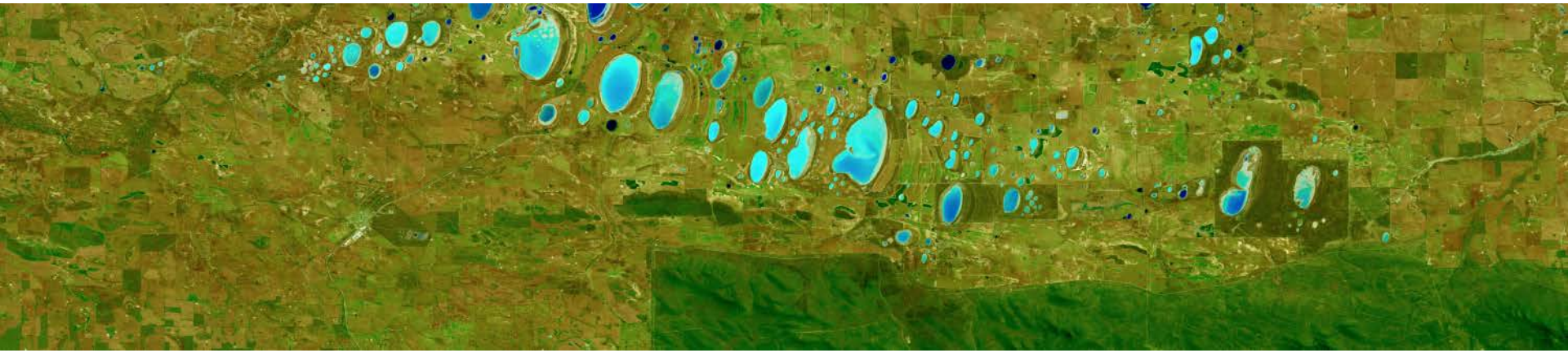
Earth Science Technology Forum

June 2020

Sustainable Land Imaging (SLI) Program

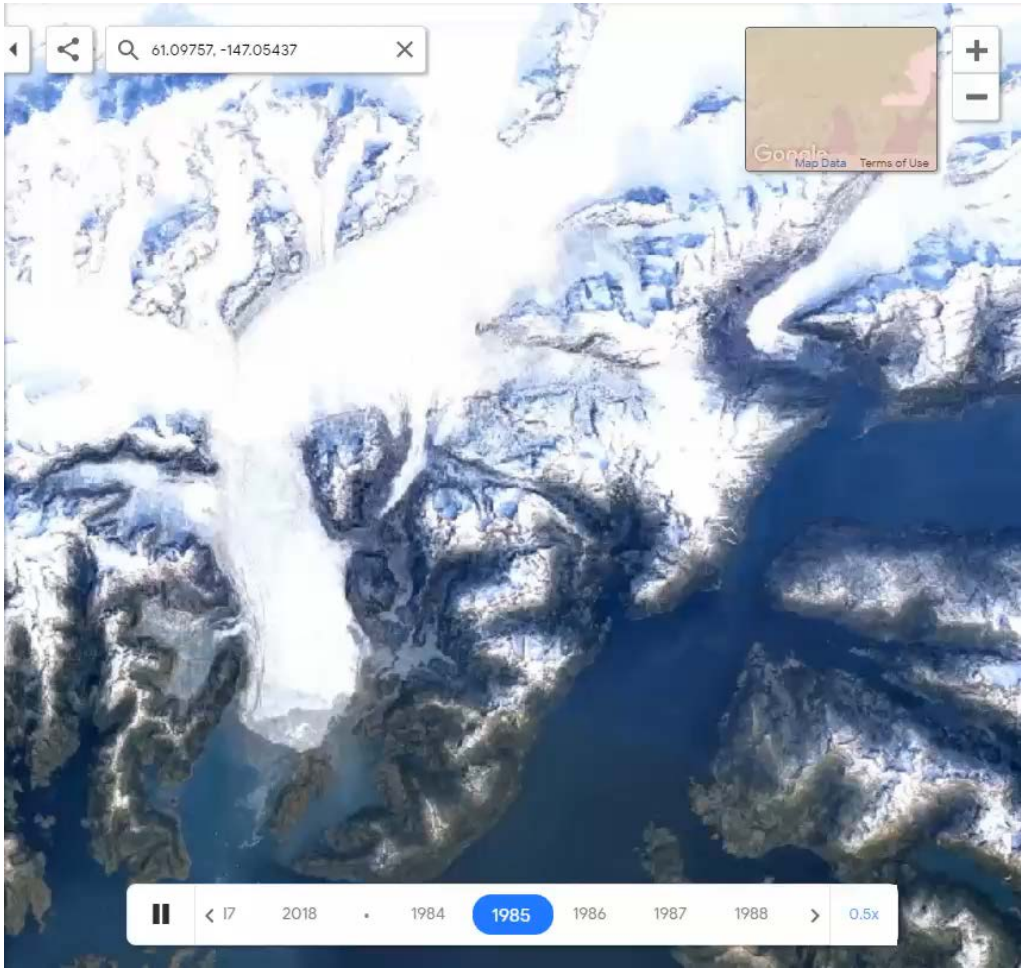
- The Sustainable Land Imaging program aims to continue the 45+ year Landsat through the development of a new generation of smaller, less costly instruments that meet or exceed current Landsat imaging capabilities

- NASA ESTO SLI-Technology (2015 ROSES A.47)
  - New measurement technologies that enable future Land Imaging
  - Reduce overall program cost



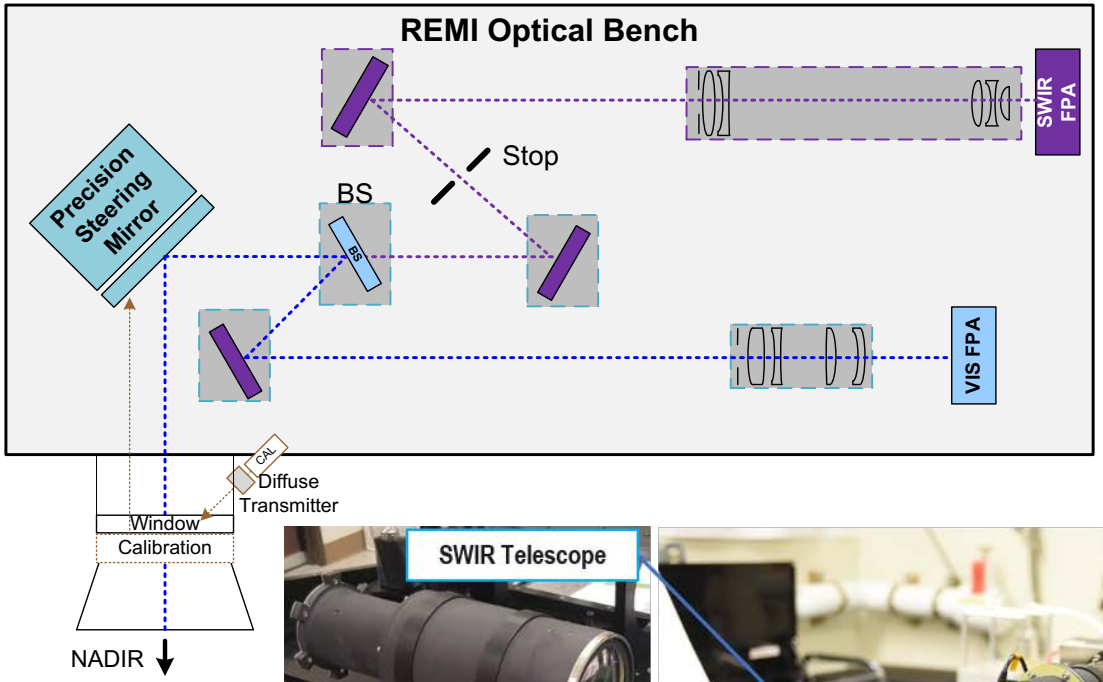
NASA / USGS

Landsat – Columbia Glacier
1984 - 2018

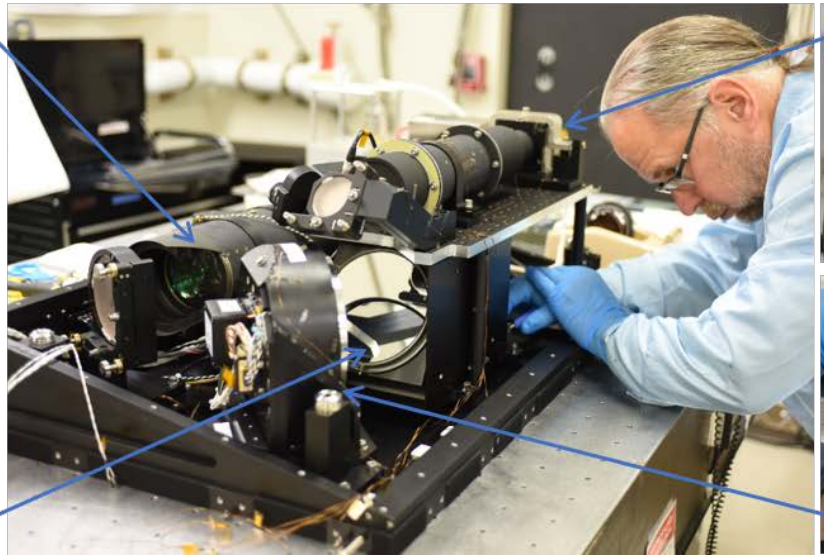


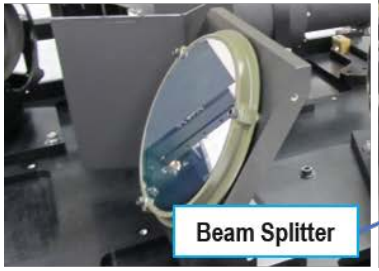
Landsat Time-lapse http://earthengine.google.com/timelapse

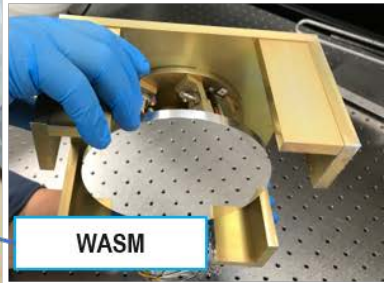
REMI Airborne Instrument Design



- Step-stare Imager
  - F/10 VNIR
  - F/4 SWIR
- 16^0 Field of View (cross-track)
- VNIR GSD 7 cm / 12m 4km / 705 km
- SWIR GSD 17 cm / 30m 4km / 705 km



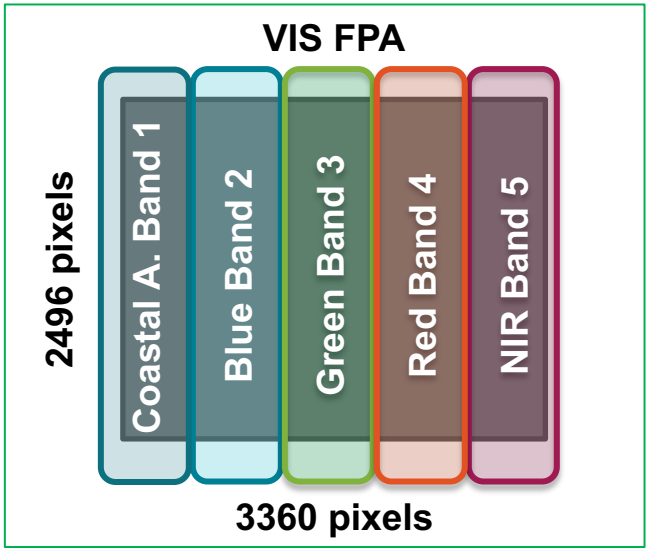




All VSWIR Spectral Bands Demonstrated

Full VSWIR optical solution for SLI-T demo

- Baseline: Enable all 5 visible bands, the Cirrus band and both SWIR bands
- 1 Visible + 1 SWIR detector



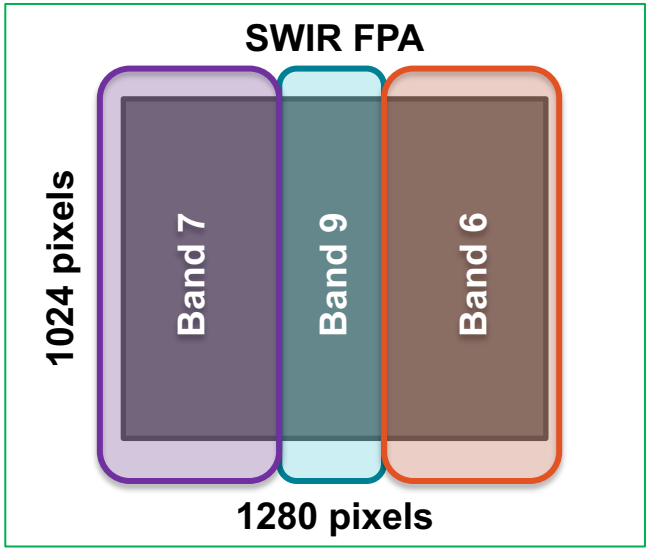


TABLE A.2 SLI-T REFERENCE MISSION SPECTRAL IMAGE PERFORMANCE REQUIREMENTS

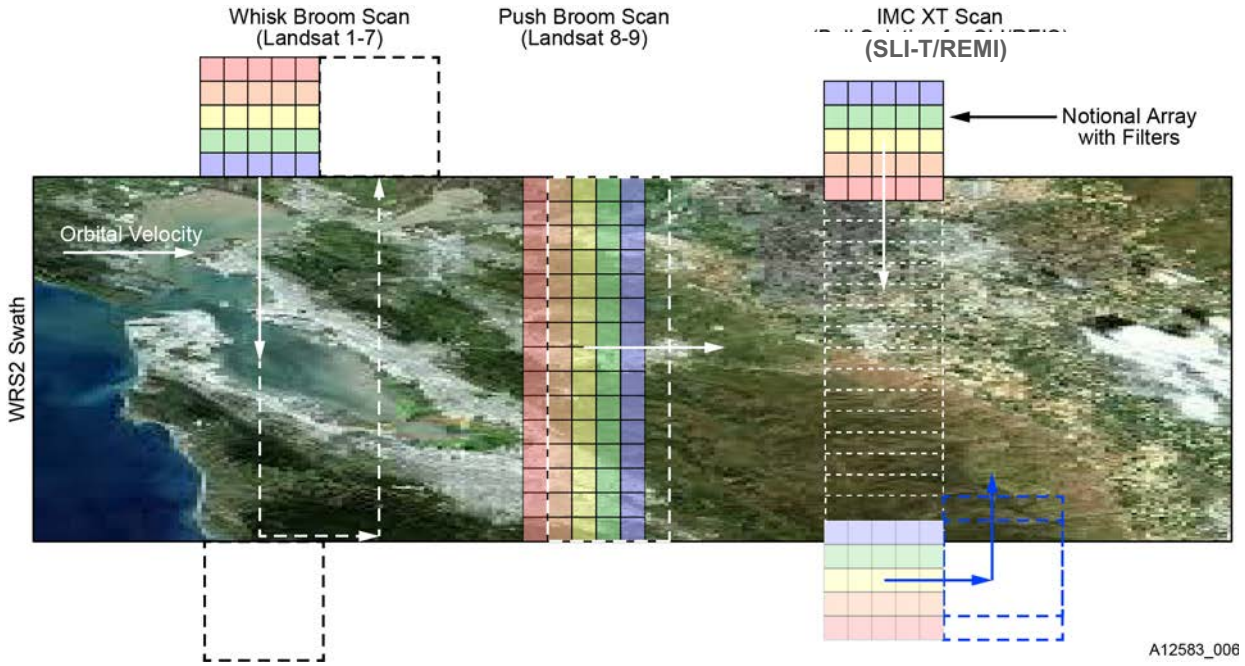
Band #	Band Name	Band #	Center Wavelength (nm)	Center Wavelength Tolerance (nm)	Minimum Lower Band Edge (nm)	Maximum Upper Band Edge (nm)
1	Coastal Aerosol	1	448	2	443	453
2	Blue	2	482	5	450	515
3	Green	3	562	5	525	600
4	Red	4	655	5	630	680
5	NIR	5	865	5	845	885
6	SWIR 1	6	1610	10	1560	1660
7	SWIR 2	7	2200	10	2100	2300
8	Panchromatic	N/A	590	10	500	680
9	Cirrus	9	1375	5	1360	1390
10	Thermal 1	N/A	10800	200	10300	11300
11	Thermal 2	N/A	12000	200	11500	12000

Image Motion Control Enables Smaller Aperture

- In optical instruments, SWaP scales with aperture
- SLI funded REIS (NASA SLI) identified that Image Motion Control (IMC)
  - IMC enables longer integration times
  - Longer integration times = greater SNR = reduced aperture for equivalent performance
- After SNR, driving requirement was relative edge response (RER)
  - RER performance is a function of
    - Motion blur
    - Optics blur
    - Detector footprint
    - Platform jitter
  - REMI utilizes IMC to further reduce motion blur and platform jitter that offset the impacts to smaller aperture
- Scan mech reduces number of required detector arrays
  - REMI = 2x detectors for VNIR – SWIR
  - OLI = 14x detectors for VNIR - SWIR

Scan Approach Opens the Design Space

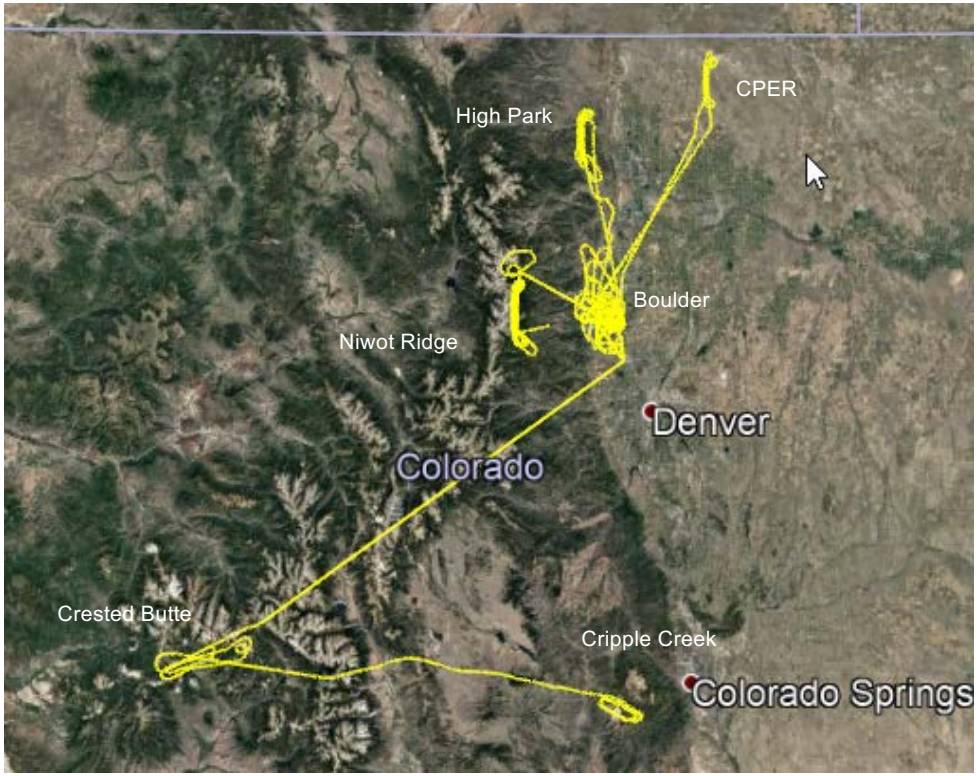
- Whisk Broom: LandSat 1-7
- Push Broom: LandSat 8 & 9 (14 detector modules)
- Step-Stare with Image Motion Correction: SLI-T/REMI



Comparison of three different scan methodologies: Whisk Broom, Push Broom, and Step-Stare.

Flight Test Status

- 3 Airborne Campaigns successfully completed
  - 2018 Engineering Flight Campaign
  - 2019 Science Flight Campaign
  - May 2020 Science Flight Campaign



Console Real-Time Viewer Images (false color)

SWIR

VNIR

Band 1 448 nm

Band 2 482 nm

Band 3 562 nm

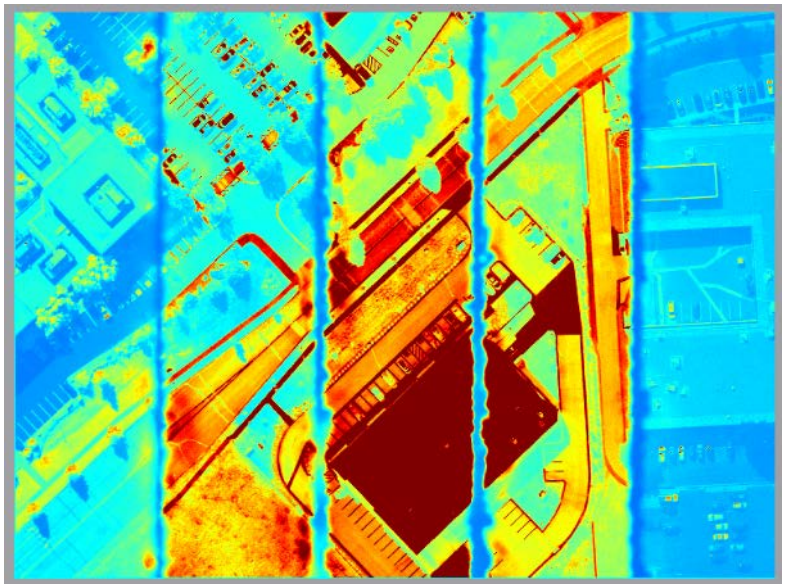
Band 4 655 nm

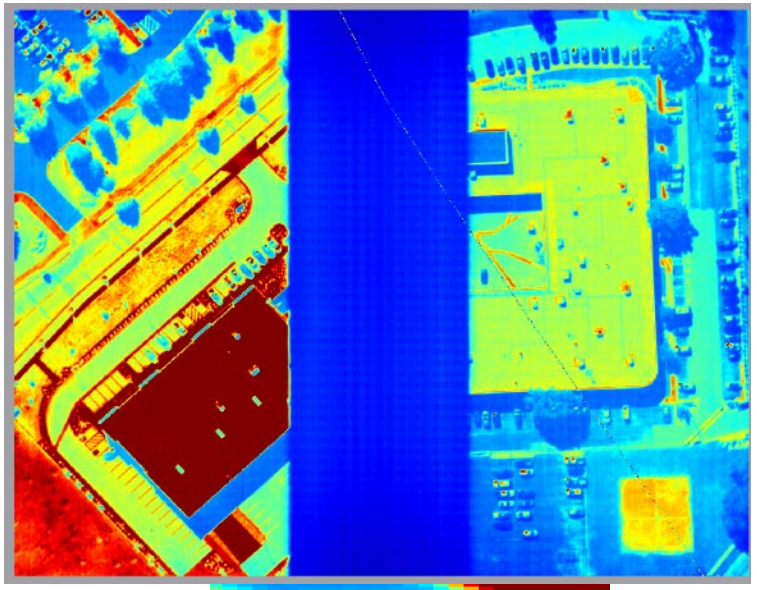
Band 5 865 nm

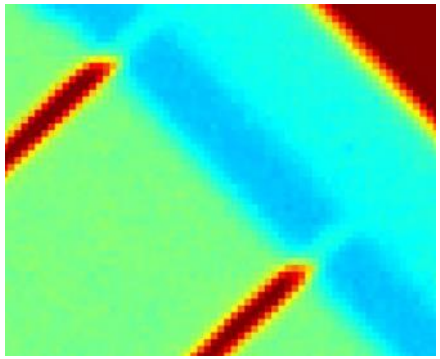
Band 7 2200 nm

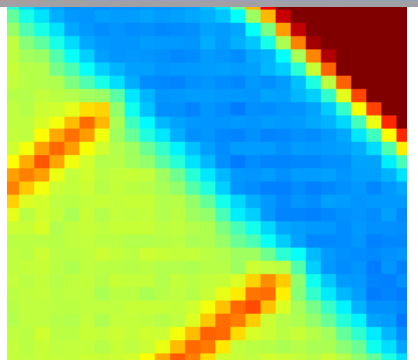
Band 9 1375 nm

Band 6 1610 nm







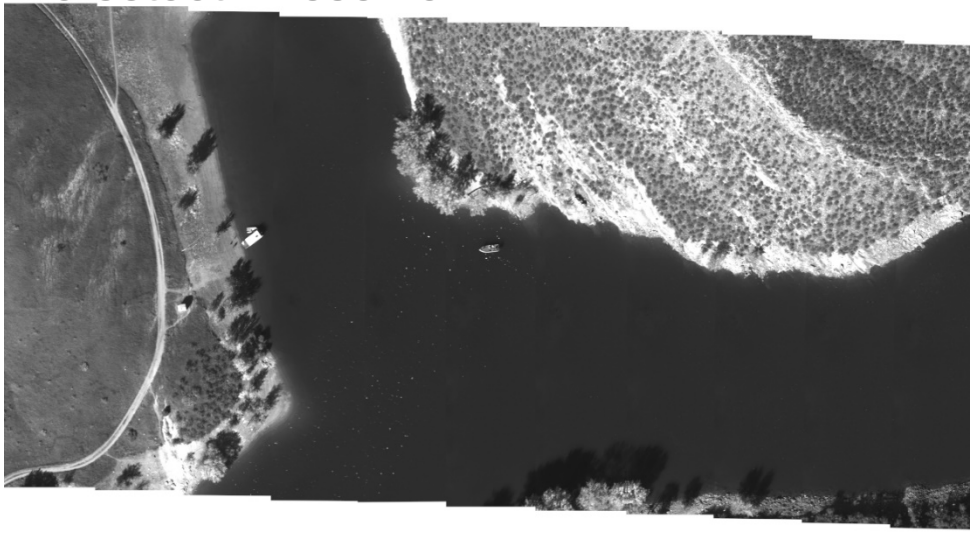


Along Track

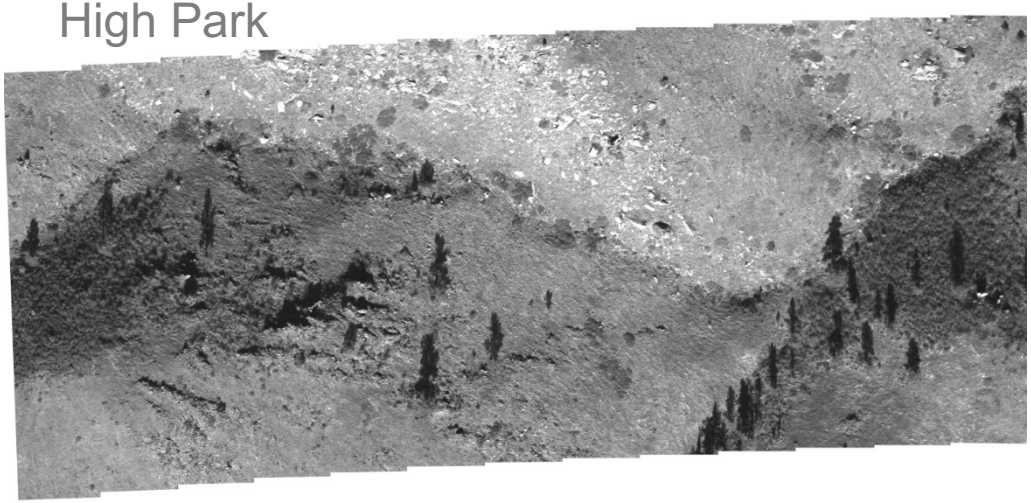
REMI Data Processing

REMI uses active image motion control to reduce motion blur and enables smaller aperture and instrument footprint while meeting SLI imaging requirements

Horsetooth Reservoir



High Park



The diverse range of targets imaged by REMI are seamlessly assembled into coherent, high-quality "OLI equivalent" scenes

REMI Real-time Operational Sucess

- REMI requires synchronizing three elements:
  - Nav data from Applanix (200Hz)
  - SWIR and VNIR frames (12.5Hz)
  - WASM angular positions (500 Hz)
- During flight, image acquisition was well synchronized with the stabilized dwells of the WASM, little motion blur in individual frames – successful stabilization
- Absolute timestamps on WASM appear to be good, allowing WASM and Nav data to be synchronized
- Active stabilization during image capture works well
- Planned swath pattern properly followed overall

Summary

- REMI utilizes a high performance scan mirror to achieve Landsat requirements with significant reduction in SWaP
  - Reduces image smear typical of Landsat instruments
  - Enables smaller aperture
  - Enables use of simple detector types
  - Key scan mirror technology has been space qualified on the GEMS and TEMPO programs
    - GEMS launched 2/2020 and is working great
- Three flight campaigns completed
  - ***Demonstrated successful use of scan mechanism for step-stare sampling of FOR and image stabilization***
  - ***Coordinate with Landsat scientists on utility of the REMI data***

Acknowledgements

- Funding from ESTO/SLI-T, Contract No. NNX16AP63G
- Ball Team:
  - Dennis Nicks, PI
  - Paul Kaptchen, PM, AI&T / Aircraft Ops
  - Nathan Leisso, Calibration
  - Betsy Farris, Systems Engineering / Flight Team
  - Madeline Cowell, Systems Engineering / Flight Team
  - Nathan Showalter, Technical Support / Flight Team
  - Tom Kampe, Optical Engineering
  - Kyle Solander, Electronics
  - Jonathan Fox, Software / Flight Team
  - Homero Gutierrez, Scan Mechanism Controls
  - Nick Polaski, Controls Implementation
  - Lyle Ruppert, L1B Data Processing